A THESIS

on

"THE EFFECT OF USING A BLEND OF PORTLAND CEMENT AND MAGNOLIA SLAG-CEMENT ON THE COMPRESSIVE STRENGTH OF CONCRETE."

Presented to the Advanced Degree Committee

of the

GEORGIA SCHOOL OF TECHNOLOGY

by

James S. Rimmer

As Part Fulfilment of the Requirements for the Degree of

Master of Science

in

Civil Engineering

Approved by

H. C. Sumn

R. S. King

T. W. Fitzgerald

Sub-committee on
Advanced Degrees

PREFACE

The data presented in this thesis was collected by the author while in the employ of the State Engineering Experiment Station at the Georgia School of Technology, Atlanta, Georgia. The author wishes to express his indebtedness to Professors F. C. Snow and J. H. Lucas of the Georgia Tech faculty under whose direction the experiments were performed.

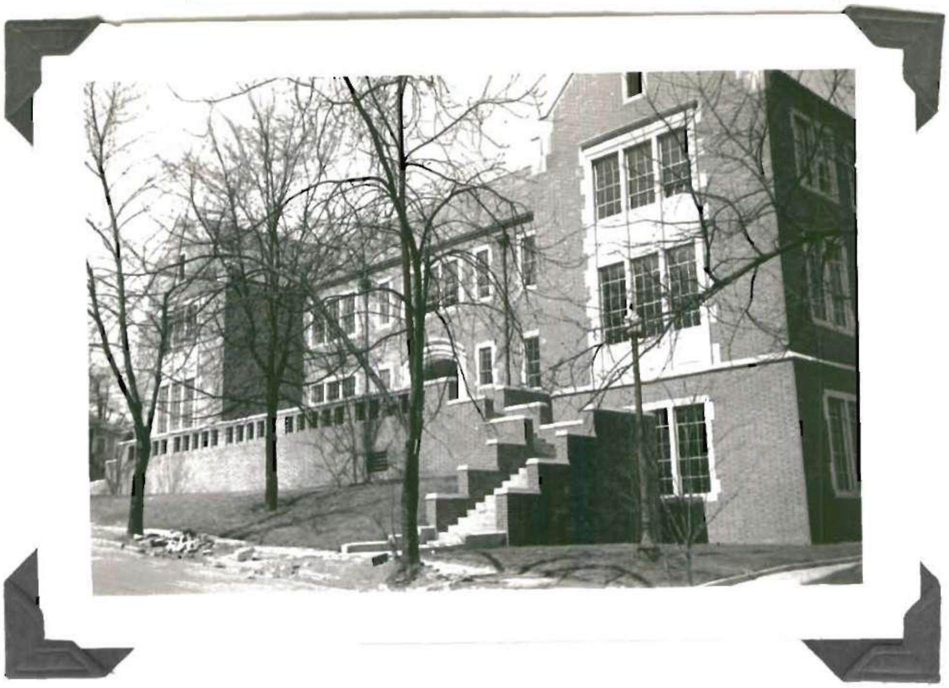
"Buildings on the Ga. Tech campus constructed with concrete containing Magnolia Slag-Cement".

Swimming Pool

Mechanical Drawing Building

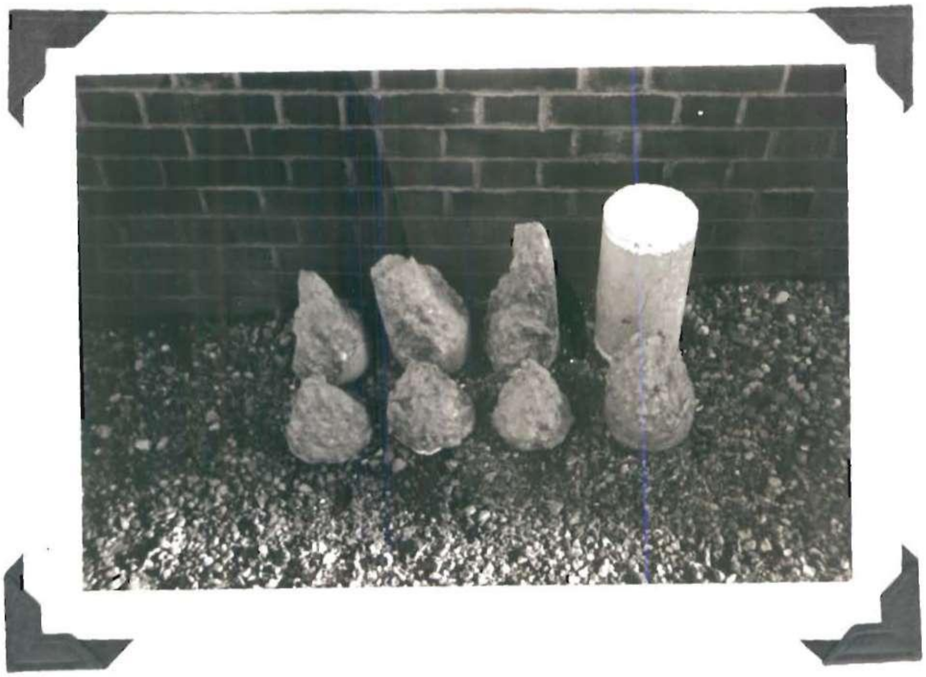
Dormitory on Williams
St. near Third St.
Side View

Dormitory on Williams
St. near North Ave.
Rear View



Magnolia Cement was used in the construction of the Civil Engineering Building on the Ga. Tech campus.

Hydraulic Press
Basement of C.E. Building



Typical Cylinder Breaks

6"x12" Concrete Cylinders in Steel Molds

"THE EFFECT OF USING A BLEND OF PORTLAND CEMENT AND MAGNOLIA SLAG-CEMENT ON THE COMPRESSIVE STRENGTH OF CONCRETE."

For some time the Southern Cement Company has had on the market a product which they call "Magnolia Cement". At first it was used only as a masonry cement. About five years ago the practice of using a blended mixture of Magnolia (high-silica) Cement and Portland Cement began. An important property of this high-silica cement was its ability to use up a portion of the free lime in the portland cement. Also, inasmuch as it is much finer than the standard portland cement, it generally tended to increase the workability of the concrete. Contractors came to use Magnolia Cement more and more. Magnolia Cement plus Portland Cement blended mixtures have been used on such projects as the Civil Engineering Building, Georgia Tech, the Clayton Disposal Plant, Atlanta, Georgia, Martin Dam on the Tallapoosa River, Alabama, and the Lowery Brothers Warehouse, Montgomery, Alabama. A more complete list of such projects can be found in the latter pages of the thesis. Contractors, Civil Engineers, and Architects began sending numerous requests to the Civil Engineering Department of Georgia Tech for definite information concerning the comparative workabilities and compressive strengths of concrete made with and without the addition of Magnolia Cement. It was to supply this information, primarily, that this thesis was written.

Many advantages are claimed, especially by the manufacturers of admixtures, for concrete in which blended mixtures are used. These include increased density of the concrete, increased strength on long-time tests, less cracking because less heat is generated during the hydrating period, a decrease in the water-cement ratio, and greatly increased workability and plasticity. Some disadvantages are the difficulty in mixing because Magnolia Cement takes up water slowly and the fact that the concrete in which the blended mixture is used attains its strength more slowly. A short discussion of these factors will be found under the heading, "Results and Discussions".

OUTLINE OF TESTS

The standard test specimen for determining the compressive strength of concrete is the 6"x12" cylinder. A total of 368 such cylinders were made, 117 being broken at seven days, 186 at 28 days, and 65 at three months. Various percentages of Magnolia Cement were used, viz., 0, 20, 25, 30, and 35. Twenty-five percent Magnolia Cement, for example, means a blend of 25% Magnolia Cement and 75% Portland Cement. This is by volume. All the concrete contained sand and coarse aggregate in the proportions of one to two, by volume. The proportion of cement was, of course, varied. All the cylinders were tested in compression with a hand-operated hydraulic press. A complete list of the cylinders is given in the tables.

MATERIALS USED IN TESTS

The coarse aggregate used was a crushed granite from Lithonia, Georgia. It had a maximum size of 3/4", a unit weight of 98 pounds per cubic foot, dry and rodded, a fineness modulus of 7.16, and an absorption of 1%.

A high quality, quartz, washed sand coming from Gailyard, Georgia, and sold under the trade name of "Rollo", was used. It had a number one organic color, a fineness modulus of about 2.00, a unit weight of 96 pounds per cubic foot, dry and rodded, a tensile strength ratio of 120 when compared with standard sand in 1-3 mortar by weight, less than 1% clay and loam, and an absorption of 1%.

Southern States Portland Cement, which is manufactured in Rockmart, Georgia, was used. This cement passed readily all the A.S.T.M. specifications.

Magnolia Slag-Cement is produced in Birmingham, Alabama. *The comparison of Magnolia and Portland from a chemical standpoint is about as follows:

*Letter in thesis. Letter from Southern Cement Co., Oct. 31, 1938.

	Lime (CaO)	Silica (SiO_2)
Magnolia Cement	49%	31.75%
Portland Cement	64%	21.75%

Magnolia Cement also passes the A.S.T.M. standards for portland cement, differing from the portland in that the normal consistency, time of initial set, and time of final set are all somewhat higher. Portland gives a greater tensile strength in the briquette tensile test. Magnolia Cement is, of course, much finer.

TECHNIQUE OF MAKING TESTS

Concrete was mixed in a non-absorbent mixing pan according to A.S.T.M. specifications (A.S.T.M. Designation: C-39-33). Sand, crushed granite, and cement were carefully weighed out on a balance. The granite was not separated on seives and recombined, but run-of-the-market granite was used. Water was measured in a 500 c.c. graduate.

Slump tests were made on all batches except the 1:3:6. Because the 1:3:6 mix borders on being harsh, a slump test on it was impractical. A slump test consists of placing the concrete in a frustrum of a cone (4" diameter at top, 8" at bottom, and 12" high) in three layers, each layer being uniformly rodded 30 times with a 5/8" round, bullet pointed rod, and slowly removing the cone vertically. The number of inches that the concrete sinks or slumps is known as the "slump". The concrete used in the slump test was placed back in the pan before the molding of specimens.

Cylindrical, 6"x12", oiled, metal molds were used. Concrete was placed in the molds in a manner similar to that used in the slump test. The molds were removed after 24 hours and the cylinders stored under water until the time of testing.

Before testing the cylinders were capped on both ends with plaster of paris. This insured the end being plane, parallel, and perpindicular to the axis of the cylinder. Several hours later they were broken in a hydraulic press equipped with a ball and socket head. A majority of the cylinders showed well-defined, conical breaks.

RESULTS AND DISCUSSION

On the next few pages are to be found the complete, tabulated results of the tests. Unless otherwise noted thereon the strength values are for one cylinder only. Following the tables are graphs drawn from the data collected. Plotted as abscissae are the water-cement ratio values while as ordinates are the compressive strengths in pounds per square inch. *This is in accordance with Professor Duff Abrams Water-Cement Ratio Law which today is generally recognized as being fundamental in concrete design. Following these is a graph which summarizes those preceding it. The general equation of the curves is $S = \frac{A}{B^{W/C}}$. S is the compressive strength in pounds per square inch, W is the volume of water used, C is the volume of cement used, and A and B are constants which are obtained by the application of the method of least squares to the observed data. A sample set of calculations (for 20% Magnolia Cement, 7 day test) can be found following the tables.

From the graphs it can be seen that Magnolia Cement materially retards the rate at which the concrete gains strength. At the three months period, however, the curve of the blend is higher than that of the all portland and it would be expected to be still higher at later periods. It is unfortunate that the one year tests could not be included in the thesis.

One might expect from what has just been said that the greater the percentage of slag-cement, the greater the strength. Practically, the differences between the curves (i.e. between the 20%, 25%, 30%, and 35% curves) at 28 days are not greater than the expected variances. Furthermore, no such generality can be drawn from the limited number of tests made.

*"Design of Concrete Mixtures", P.C.A.

The value of the strength curves is that they provide curves from which mixes to give different strengths can be designed, or that knowing the water-cement ratio, one can predict the compressive strength.

*The fact that the rate of setting is retarded in concrete where Magnolia Cement is used is an advantage because this tends to reduce cracking and promotes watertightness. On the other hand, it would be disadvantageous on a rush job where the concrete must be placed in service as soon as possible.

Following the strength graphs is a graph illustrating the effect of Magnolia Cement on the slump of the 1:2:4 mix (by volume). This curve, of course, holds only for the materials used and not for all types, sizes, and gradings of aggregates. Plotted as abscissae are the water-cement ratio values while as ordinates are the slumps (inches). It can be seen that there is one-half inch difference between the curves. The difference would probably decrease with the use of a finer sand and increase if a coarser graded sand were used. An effect that the author has noticed at times is that concrete containing Magnolia Cement seems to segregate less easily, i.e., the mortar seems to support the coarse aggregate better during the preliminary settling into the forms and while the first set is taking place.

It must be noted that the Magnolia Cement is not "added" to the mix but "replaces" a portion of the portland cement. In this sense it is not really an admixture. Not only does it increase the amount of finess but it also contributes its share of the compressive strength. This is in contrast to the true admixtures which must be added to the mix. Magnolia and Portland Cement cost about the same at the present time; therefore, Magnolia Cement does not add to the cost of the mix. Any admixture since it must be added would increase the cost of the mix by the cost of itself.

*"Slag-Cement Blend Tried at Norris Dam", Eng. News Record, Dec. 19, 1935.

CONCLUSIONS

1. Compressive Strength. Magnolia Cement retards, at the early ages, the hardening of the concrete. However, at the three months period the strength of concrete with and without the admixture is about the same.
2. Workability. Magnolia Cement adds to the general workability of the concrete. It is quite possible, when course, poorly graded aggregates are used, to obtain more strength at a given slump using Magnolia Cement in the mix than when using portland only. Magnolia Cement also adds to the stickiness of the mix, preventing air pockets and helping therefore to prevent honeycombing and at the same time aiding in placing. As an example consider a 1:2:4 mix (by volume) which is to have a 5" slump. Using all portland cement, a water-cement ratio of 0.985 is required. Using 25% Magnolia Cement, a water-cement ratio of 0.950 is required. Both concretes could be expected to attain a compressive strength of 3100 pounds per square inch at 28 days. This is for the well graded aggregates used in this research.

The chief value of the data presented is that it provides a curve from which concrete made using Portland and Magnolia blends can be designed for a given strength.

When it comes to evaluating an admixture one must remember that it is possible to accomplish the same result in many ways. One might change the aggregate gradings, use more portland cement, change the mix, or even use one of the true admixtures. By a true admixture is meant any finely divided material which is added to concrete to add to its workability. It is imperative that the combination which is most economical commensurate with the other desirable properties of the concrete be used.

BIBLIOGRAPHY

1. F. R. McMillan, "Basic Principles of Concrete Making", McGraw- Hill, Inc., New York, 1929.
2. W. F. Kellerman and D. G. Runner, "The Effect of Using a Blend of Portland and Natural Cement on the Physical Properties of Mortar and Concrete", Public Roads Magazine, Vol. 19, No. 8, October 1938.
3. R. E. Mills and R. B. Creeps, "Physical Properties of Speed Portland and Blended Cement Mortars and Concretes", Bulletin 47, Eng. Expt. Station, Purdue University.
4. "Slag-Cement Blend Tried at Norris Dam", Eng. News-Record, Dec. 19, 1935.
5. "Effect of Hydrated Lime and Other Powdered Admixtures in Concrete", Duff A. Abrams, P.C.A. Bulletin No. 8.
6. T. C. Powers, "Studies of Workability of Concrete", Journal of A.C.I., Feb., 1932, Volume 28, Page 429.
7. T. C. Powers and F. R. McMillan, "A Method of Evaluating Admixtures", Journal of A.C.I., March-April 1934, Volume 30, Page 325.
8. T. C. Powers and F. R. McMillan, "Classification of Admixtures as to Pozzolanic Effect by Means of Compressive Strength of Concrete", Journal of A.C.I., November-December, 1934, Volume 34.
9. Portland Cement Association, "The Design and Control of Concrete Mixtures", 1936.
10. Duff A. Abrams, "Calcium Chloride as an Admixture in Concrete", Bulletin 13, Portland Cement Association.
11. A.S.T.M. Standards, 1937.
12. Talbot and Richart, "The Strength of Concrete; Its Relation to the Cement, Aggregates, and Water". Bulletin 137, Eng. Exp. Sta., University of Illinois, 1923.

7 DAY TEST

20% MAGNOLIA CEMENT 80% PORTLAND CEMENT					25% MAGNOLIA CEMENT 75% PORTLAND CEMENT				
LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH	LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
78	1-1½-3	3½"	0.719	2860#/□"	64	1-1½-3	3½"	0.691	3330#/□"
79	1-2-4	3¾	0.890	2180	65	1-2-4	3½	0.880	2090
80	1-2½-5	3¾	1.052	1240	66	1-2½-5	3¼	1.078	1380
81	1-3-6	2½	1.278	1010	67	1-3-6	3	1.293	1110
82	1-1½-3	6⅝	0.725	3020	94	1-1½-3	6	0.753	2770
83	1-1½-3	3¼	0.688	3160	146	1-1½-3	1⅝	0.676	3200
85	1-2-4	6	0.962	1780	146-A	1-1½-3	1	0.661	3470
86	1-2½-5	6	1.208	1160	148	1-1½-3	7¾	0.844	2060
147	1-1½-3	11/16	0.659	3510	152	1-2-4	⅝	0.826	2400
149	1-1½-3	7¾	0.870	2130	155	1-2½-5	¾	0.975	1420
153	1-2-4	13/16	0.856	2180	159	1-3-6	7/16	1.275	1060
156	1-2½-5	1 1/16	1.010	1400	190	1-1½-3	1½	0.725	3360
160	1-3-6	11/16	1.242	980	192	1-1½-3	2¼	0.725	3520
195	1-1½-3	3½	0.725	3690	193	1-1½-3	2¾	0.725	3450
196	1-1½-3	6½	0.805	2710	194	1-1½-3	7	0.805	2800
208	1-2-4	2½	0.894	2310	207	1-2-4	2¾	0.894	2310
212	1-2-4	5½	0.966	1920	211	1-2-4	5⅛	0.966	1560
216	1-2½-5	3½	1.118	1380	215	1-2½-5	4⅛	1.118	1330
221	1-3-6	NO TEST	1.290	1110	220	1-3-6	NO TEST	1.290	1070
234	1-1½-3	3¾	0.723	3200	230	1-1½-3	4¼	0.723	3200
235	1-2-4	3	0.894	2130	231	1-2-4	3⅜	0.894	2270
236	1-2½-5	3⅛	1.120	1420	232	1-2½-5	5	1.120	1220
237	1-3-6	1½	1.263	1110	233	1-3-6	1⅞	1.263	1020

7 DAY TEST

30% MAGNOLIA CEMENT
70% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH #/□"
68	1-1½-3	3½"	0.683	3160
69	1-2-4	4	0.818	1910
70	1-2½-5	3	1.041	1160
71	1-3-6	4	1.275	800
87	1-1½-3	6½	0.758	2440
88	1-1½-3	6½	0.758	2220
89	1-2-4	6½	0.930	1730
92	1-1½-3	8	0.791	2050
145	1-1½-3	1⅜	0.659	3160
145-A	1-1½-3	¾	0.668	3980
151	1-2-4	¾	0.814	2090
154	1-2½-5	¾	0.974	1510
158	1-3-6	9/16	1.218	1020
187	1-1½-3	2¾	0.725	3240
188	1-1½-3	5⅞	0.805	2650
206	1-2-4	2½	0.894	2090
210	1-2-4	5⅞	0.966	1690
214	1-2½-5	NO TEST	1.118	1170
219	1-3-6	" "	1.290	930
226	1-1½-3	2⅜	0.723	3020
227	1-2-4	3¾	0.894	2180
228	1-2½-5	4⅛	1.120	1320
229	1-3-6	3⅜	1.263	910

35% MAGNOLIA CEMENT
65% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH #/□"
72	1-1½-3	3½"	0.698	2930
73	1-2-4	4	0.870	1870
74	1-2½-5	6½	1.184	1240
75	1-2½-5	4	1.052	1260
76	1-2½-5	¾	0.943	1690
77	1-3-6	6	1.314	820
90	1-1½-3	6	0.740	2800
91	1-1½-3	8	0.839	1690
93	1-2-4	6½	0.940	1690
144	1-1½-3	3	0.725	2620
144-A	1-1½-3	1	0.669	3560
150	1-2-4	⅞	0.826	2400
157	1-3-6	9/16	1.251	800
185	1-1½-3	3	0.725	3350
186	1-1½-3	7¼	0.830	2400
205	1-2-4	2¾	0.894	2050
209	1-2-4	6⅞	0.966	1480
213	1-2½-5	NO TEST	1.118	1290
217	1-2½-5	⅞	1.010	1560
218	1-3-6	NO TEST	1.290	930
222	1-2-4	3¼	0.894	2050
223	1-1½-3	1⅞	0.723	3030
224	1-2½-5	4⅞	1.120	1200
225	1-3-6	3½	1.263	980

OTE: STRENGTHS BELOW DOTTED LINE ARE AVERAGE OF TWO VALUES.

28 DAY TEST

20% MAGNOLIA CEMENT
80% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
98	1-1½-3	3¾	0.708	5070#/□"
103	1-2-4	6½	0.949	2830
104	1-2-4	3¾	0.889	3160
105	1-2-4	7/8	0.820	3730
106	1-2-4	7½	1.072	2000
107	1-2-4	6½	0.948	2270
115	1-2½-5	3½	1.108	2050
123	1-1½-3	5/8	0.652	5560
125	1-1½-3	7/8	0.817	3290
133	1-2½-5	5/8	1.030	2600
143	1-3-6	3/4	1.251	1760
195	1-1½-3	3½	0.725	5420
196	1-1½-3	6½	0.805	4310
208	1-2-4	2½	0.894	4000
212	1-2-4	5½	0.966	3490
216	1-2½-5	3½	1.118	2420
221	1-3-6	NO TEST	1.290	1780
299	1-1½-3	4¼	0.725	4800
301	1-2-4	2¼	0.894	3540
303	1-2½-5	3	1.075	2400
305	1-3-6	NO TEST	1.182	1970
307	1-1½-3	4½	0.750	4470
309	1-2-4	5	0.930	3510
311	1-2½-5	4⅜	1.030	2480
313	1-2-4	4½	0.860	3580
314	1-2½-5	1½	1.030	2610
316	1-2½-5	2¾	1.120	2250
318	1-1½-3	1⅞	0.698	5130
320	1-3-6	NO TEST	1.128	1980
324	1-1½-3	5⅞	0.777	4240
326	1-2-4	3⅜	0.860	3290
328	1-2-4	3/8	0.824	3540
322	1-2-4	1¼	0.860	3380
330	1-2½-5	3¾	1.118	2170
332	1-3-6	NO TEST	1.236	1730
334	1-2½-5	" "	1.163	1890
335	1-2½-5	3⅞	1.118	2290

25% MAGNOLIA CEMENT
75% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
97	1-1½-3	3½"	0.698	5170#/□"
102	1-2-4	3⅞	0.881	2760
110	1-2-4	6¼	0.940	2490
114	1-2½-5	3⅞	1.087	2030
116	1-1½-3	6¼	0.815	3800
122	1-1½-3	1¾	0.684	5160
122-A	1-1½-3	7/8	0.659	5440
124	1-1½-3	7¾	0.818	3240
128	1-2-4	7/8	0.828	4090
132	1-2½-5	3/4	1.008	2800
136	1-3-6	2⅞	1.353	1510
139	1-3-6	1½	1.413	1510
142	1-3-6	1⅛	1.290	1730
193	1-1½-3	2¾	0.725	5510
194	1-1½-3	7	0.805	4710
207	1-2-4	2¾	0.894	4090
211	1-2-4	5⅛	0.966	3160
215	1-2½-5	4⅛	1.118	2360
220	1-3-6	NO TEST	1.290	1780
274	1-2-4	7/8	0.860	3560
275	1-2-4	1⅞	0.894	3400
276	1-2-4	2¼	0.930	3240
277	1-2-4	5⅛	0.966	3020
278	1-2-4	2⅝	0.930	3160
279	1-2½-5	1	1.075	2420
280	1-2½-5	1⅝	1.118	2120
281	1-2½-5	2⅝	1.161	2110
282	1-2½-5	2⅜	1.208	2080
283	1-1½-3	1⅞	0.725	5340
284	1-1½-3	3⅛	0.750	5020
285	1-1½-3	5½	0.777	4490
286	1-1½-3	2¼	0.698	5440
287	1-3-6	NO TEST	1.233	1640
288	1-3-6	" "	1.290	1530
289	1-3-6	" "	1.185	1690
491	1-2-4	3	0.898	3300

NOTE: STRENGTHS BELOW DOTTED LINES ARE AVERAGE OF TWO VALUES.

28 DAY TEST

30% MAGNOLIA CEMENT
70% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
96	1-1½-3	3¼	0.691	5330 #/□"
101	1-2-4	4	0.876	3180
109	1-2-4	6½	0.932	2890
113	1-2½-5	3	1.066	2130
117	1-1½-3	7¼	0.840	3910
121	1-1½-3	7/8	0.684	5070
127	1-2-4	1	0.812	3780
131	1-2½-5	1 3/16	1.025	2580
141	1-3-6	5/8	1.299	1660
206	1-2-4	2½	0.894	3910
210	1-2-4	5 7/8	0.966	3470
214	1-2½-5	NO TEST	1.118	2060
219	1-3-6	" "	1.290	1870
298	1-1½-3	3 3/8	0.723	4640
300	1-2-4	2¼	0.894	3330
302	1-2½-5	2	1.075	2220
304	1-3-6	NO TEST	1.182	1760
306	1-1½-3	3 5/8	0.750	4790
308	1-2-4	3 5/8	0.930	3180
310	1-2½-5	1¾	1.030	2530
312	1-2-4	3¾	0.860	3190
315	1-2½-5	4¼	1.120	2350
317	1-1½-3	2	0.698	4800
319	1-3-6	NO TEST	1.128	1820
323	1-1½-3	6	0.777	4090
325	1-2-4	2	0.860	3440
327	1-2-4	7/8	0.824	3720
329	1-2½-5	2½	1.118	2140
321	1-2-4	1 7/8	0.860	3690
331	1-3-6	NO TEST	1.236	1580
333	1-2½-5	4½	1.118	1880

35% MAGNOLIA CEMENT
65% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
95	1-1½-3	3	0.715	4400 #/□"
99	1-1½-3	3¼	0.694	5250
111	1-2-4	5½	0.930	2800
112	1-2½-5	2½	1.119	2290
112-A	1-2½-5	2½	1.141	2240
112-B	1-2½-5	3	1169	2090
116	1-1½-3	6¼	0.830	3780
120	1-1½-3	1¼	0.690	4930
120	1-2-4	7/8	0.830	3630
129	1-2½-5	4 7/8	1.250	1620
130	1-2½-5	1	1.000	2620
134	1-3-6	3 7/8	1.359	1380
140	1-3-6	¾	1.305	1580
205	1-2-4	2¾	0.894	3690
209	1-2-4	6 7/8	0.966	3040
213	1-2½-5	NO TEST	1.118	2440
217	1-2½-5	7/8	1.010	2890
218	1-3-6	NO TEST	1.290	1960
258	1-2-4	3 3/8	0.860	3600
259	1-2-4	4	0.894	3400
260	1-2-4	4½	0.930	3410
261	1-2-4	5/8	0.842	3520
262	1-2½-5	1	0.988	2600
263	1-2½-5	2¾	1.075	2190
264	1-2½-5	1 7/8	1.028	2370
265	1-2½-5	4	1.118	2140
266	1-1½-3	2 1/8	0.697	5690
267	1-1½-3	3¼	0.725	5070
268	1-1½-3	5 3/8	0.750	4980
269	1-1½-3	5 3/8	0.777	4780
270	1-3-6	NO TEST	1.233	1820
271	1-3-6	" "	1.185	1780
272	1-3-6	" "	1.290	1660
273	1-3-6	" "	1.128	1980

NOTE: STRENGTHS BELOW DOTTED LINE ARE AVERAGE OF TWO VALUES.

28 DAY TEST

100% PORTLAND CEMENT

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
161	1-1½-3	5⅞	0.795	5160 #/□"
162	1-2-4	6½	1.030	3380
163	1-2½-5	4	1.140	2680
164	1-3-6	½	1.188	2270
165	1-1½-3	3½	0.741	5070
166	1-2-4	3⅛	0.938	3420
167	1-2½-5	¾	1.092	2840
169	1-1½-3	¾	0.675	5730
170	1-2-4	⅞	0.878	4440
171	1-2½-5	2⅜	1.133	2760
172	1-1½-3	6¾	0.855	4400
173	1-2-4	7⅛	1.082	2670
174	1-2½-5	5¾	1.292	1910
197	1-1½-3	2⅝	0.725	5160
198	1-2-4	3⅞	0.930	3650
199	1-2-4	6⅝	1.000	3420
200	1-2-4	2	0.860	4000
201	1-1½-3	6¼	0.791	4980
202	1-2½-5	3⅝	1.118	2530
203	1-2½-5	1¼	1.028	3070
242	1-2-4	1¼	0.860	3800
243	1-2-4	2¾	0.894	3450
244	1-2-4	5⅞	0.964	3020
246	1-2½-5	⅜	0.943	2760
247	1-2½-5	1½	1.030	2800
248	1-2½-5	5⅛	1.118	2360
249	1-2½-5	2¼	1.075	2530
251	1-1½-3	3½	0.725	5140
252	1-1½-3	4⅝	0.777	4670
253	1-1½-3	7⅛	0.830	4440
252-A	1-1½-3	5¾	0.777	4600
254	1-3-6	NO TEST	1.290	1820
255	1-3-6	" "	1.236	1980

LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
256	1-3-6	NO TEST	1.185	1860 #/□"
257	1-3-6	" "	1.128	2020
290	1-2-4	1¼"	0.894	3580
291	1-2½-5	1½	1.075	2530
292	1-1½-3	2⅛	0.725	4850
293	1-3-6	NO TEST	1.233	1870
294	1-2-4	4⅝	0.966	3320
295	1-2½-5	4¼	1.118	2260
296	1-2-4	1⅞	0.860	4000
297	1-2½-5	1⅜	1.028	2890
549	1-2-4	3	0.894	3250
550	1-2½-5	2½	1.075	2200
551	1-2.16-3.84	6¼	0.924	3300
552	1-2.52-4.48	4½	1.038	2350
553	1-2.88-5.12	3¾	1.140	1950
565	1-2-4	NO TEST	0.898	
490	1-2-4	3¾	0.890	3750

NOTE: STRENGTHS BELOW DOTTED LINE ARE AVERAGE OF TWO VALUES.

3 MONTH TEST

25% MAGNOLIA CEMENT 75% S.S. PORTLAND					100% S.S. PORTLAND CEMENT				
LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH	LAB. NO.	MIX (VOL.)	SLUMP	W/C RATIO	STRENGTH
336	1-2-4	1¾"	0.860	4050#/□	346	1-1½-3	2½"	0.725	5730#/□
337	1-2-4	2¾	0.894	3600	349	1-1½-3	4	0.750	5470
338	1-2-4	4 11/16	0.930	3675	350	1-1½-3	3⅛	0.778	4980
340	1-2-4	5	0.948	3820	351	1-1½-3	6⅞	0.790	5020
341	1-2½-5	1¼	1.075	2670	356	1-2-4	1¾	0.894	4000
342	1-2½-5	3⅜	1.118	2440	357	1-2-4	2¾	0.930	3820
343	1-2½-5	2½	1.098	2310	358	1-2-4	4½	0.966	3600
344	1-2½-5	3¼	1.140	2710	359	1-2-4	2½	0.930	3690
347	1-1½-3	3	0.750	5870	360	1-2-4	3⅞	0.950	3820
348	1-1½-3	4⅞	0.778	5420	361	1-2½-5	2½	1.118	2530
352	1-1½-3	4⅞	0.790	5290	362	1-2½-5	2	1.077	2820
353	1-3-6	NO TEST	1.209	2220	363	1-2½-5	3⅜	1.162	2400
354	1-3-6	" "	1.263	2130	364	1-2½-5	4⅛	1.140	2530
355	1-3-6	" "	1.236	1960	366	1-3-5	NO TEST	1.200	2310
373	1-2½-4½	" "	1.081	3240	367	1-2½-4½	" "	1.082	2760
374	1-2-4	6¼	1.000	3600	368	1-3-5	" "	1.243	2200
375	1-1½-3	6⅜	0.804	5330	369	1-2½-5	" "	1.122	2770
376	1-2½-5	4⅛	1.163	2600	370	1-3-6	" "	1.263	1890
377	1-2½-4½	NO TEST	1.122	2670	371	1-3-6	" "	1.209	1960
379	1-2½-4½	" "	1.044	3020	431	1-1½-3	7½	0.778	5150
443	1-1¾-3½	2½	0.782	4850	432	1-1¾-3½	7⅛	0.875	4270
444	1-2¼-4½	4⅛	1.005	3250	433	1-2-4	6⅞	0.966	3750
445	1-2¾-5½	NO TEST	1.183	2180	434	1-2¼-4½	5½	1.005	3550
446	1-1¾-3½	4⅝	0.815	4150	435	1-2½-5	4¾	1.075	2660
447	1-2¼-4½	3½	0.968	3350	436	1-2¾-5½	NO TEST	1.133	2260
448	1-2¾-5½	NO TEST	1.230	2200	437	1-3-6	" "	1.185	2180
449	1-1¾-3½	6¼	0.846	4750	438	1-1¾-3½	5¾	0.814	4650
450	1-2¼-4½	5	1.047	3200	439	1-1¾-3½	3	0.753	5550
451	1-2¾-5½	NO TEST	1.133	2300	440	1-2¼-4½	2	0.926	3750
452	1-3-6	" "	1.290	1810	441	1-2¾-5½	NO TEST	1.088	2500
453	1-2½-5	4	1.075	2900	442	1-2¼-4½	2⅜	0.968	3750
454	1-2-4	3	0.894	4100	479	1-2-4	3½	0.898	4050
480	1-2-4	3½	0.898	3850					

NOTE: EACH STRENGTH SHOWN BELOW DOTTED LINE IS THE AVERAGE OF TWO VALUES.

20% MAGNOLIA CEMENT 80% PORTLAND CEMENT 7 DAY TEST

APPLICATION OF THE METHOD OF LEAST SQUARES TO THE OBSERVED DATA.

NUMBER	W/C RATIO	STRENGTH #/□"	LOG S	W/C LOG S	$(W/C)^2$
78	0.719	2860	3.4564	2.4852	0.5170
79	0.890	2180	3.3385	2.9712	0.7921
80	1.052	1240	3.0934	3.2543	1.1067
81	1.278	1010	3.0043	3.8395	1.6333
82	0.725	3020	3.4800	2.5230	0.5256
83	0.688	3160	3.4997	2.4078	0.4733
85	0.962	1780	3.2504	3.1269	0.9254
86	1.208	1160	3.0645	3.7019	1.4593
147	0.659	3510	3.5453	2.3364	0.4343
149	0.870	2130	3.3284	2.8957	0.7569
153	0.856	2180	3.3385	2.8578	0.7327
156	1.010	1400	3.1461	3.1776	1.0201
160	1.242	980	2.9912	3.7151	1.5426
195	0.725	3690	3.5670	2.5861	0.5256
196	0.805	2710	3.4330	2.7636	0.6480
208	0.894	2310	3.3636	3.0071	0.7992
212	0.966	1920	3.2833	3.1717	0.9332
216	1.118	1380	3.1399	3.5104	1.2499
221	1.290	1110	3.0453	3.9284	1.6641
234	0.723	3200	3.5052	2.5343	0.5227
235	0.894	2130	3.3284	2.9756	0.7992
236	1.120	1420	3.1523	3.5306	1.2544
237	1.263	1110	3.0453	3.8462	1.5952
TOTALS:	21.957		75.4000	71.1464	21.9108

GENERAL EQUATION OF CURVE: $S = \frac{A}{B^{W/C}}$

A AND B ARE CONSTANTS TO BE DETERMINED.

W/C = WATER-CEMENT RATIO (VOLUME)

S = COMPRESSIVE STRENGTH IN LBS./SQ. INCH.

TAKE LOGARITHM OF GENERAL EQUATION:

(1) $\log S + W/C \log B = \log A$

MULTIPLY (1) BY W/C: (2) $W/C \log S + (W/C)^2 \log B = W/C \log A$

SUBSTITUTING (1) $21.957 \log B + 75.4 = 23 \log A$

(2) $21.9108 \log B + 71.1464 = 21.957 \log A$

SOLVING: $\log A = 4.1172$, $\log B = 0.8787$

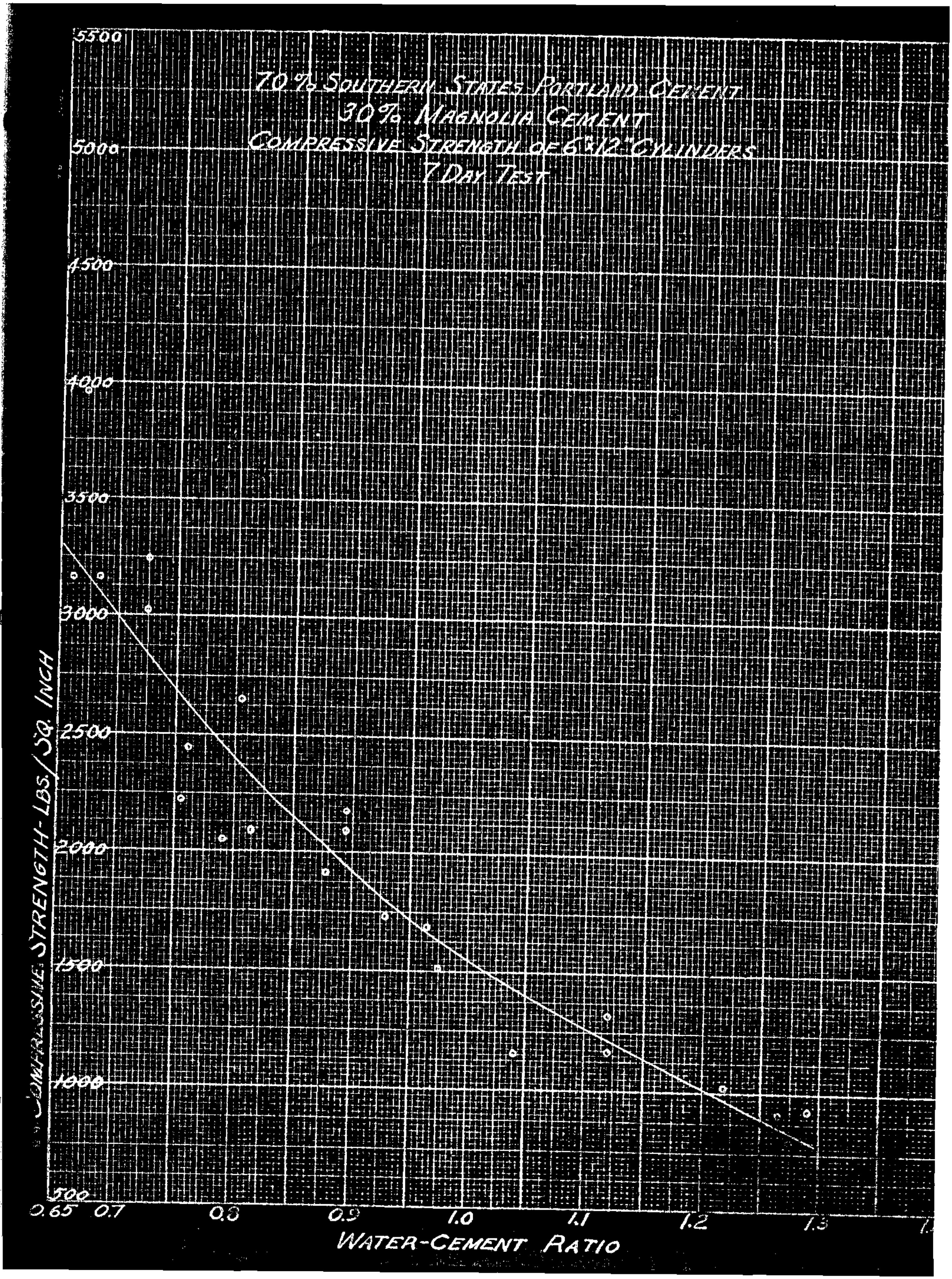
LOG A AND LOG B ARE SUBSTITUTED IN EQUATION 1 AND THE TABLE ON THE RIGHT OBTAINED.

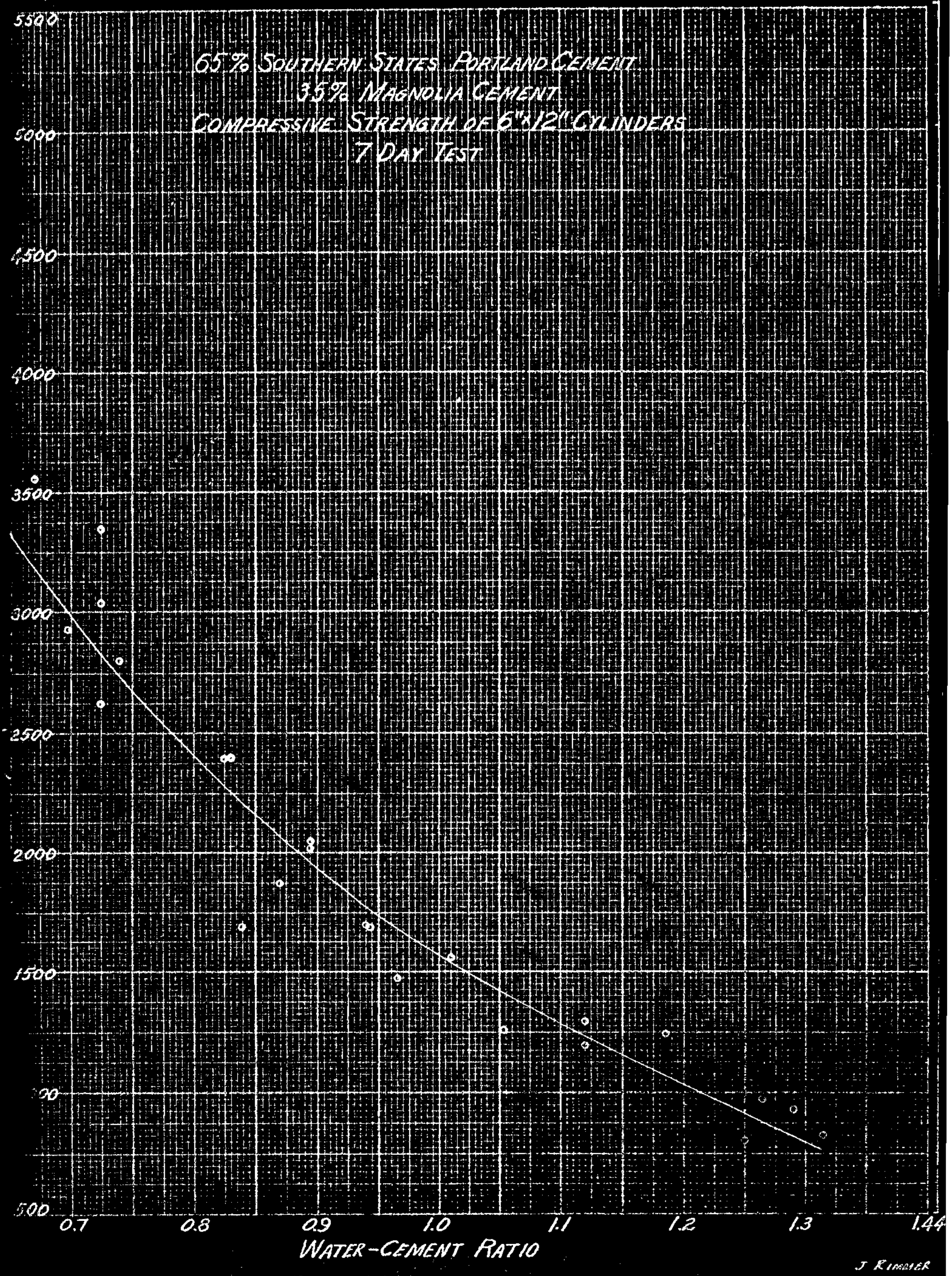
EQUATION IS $S = 13100/7.56^{W/C}$

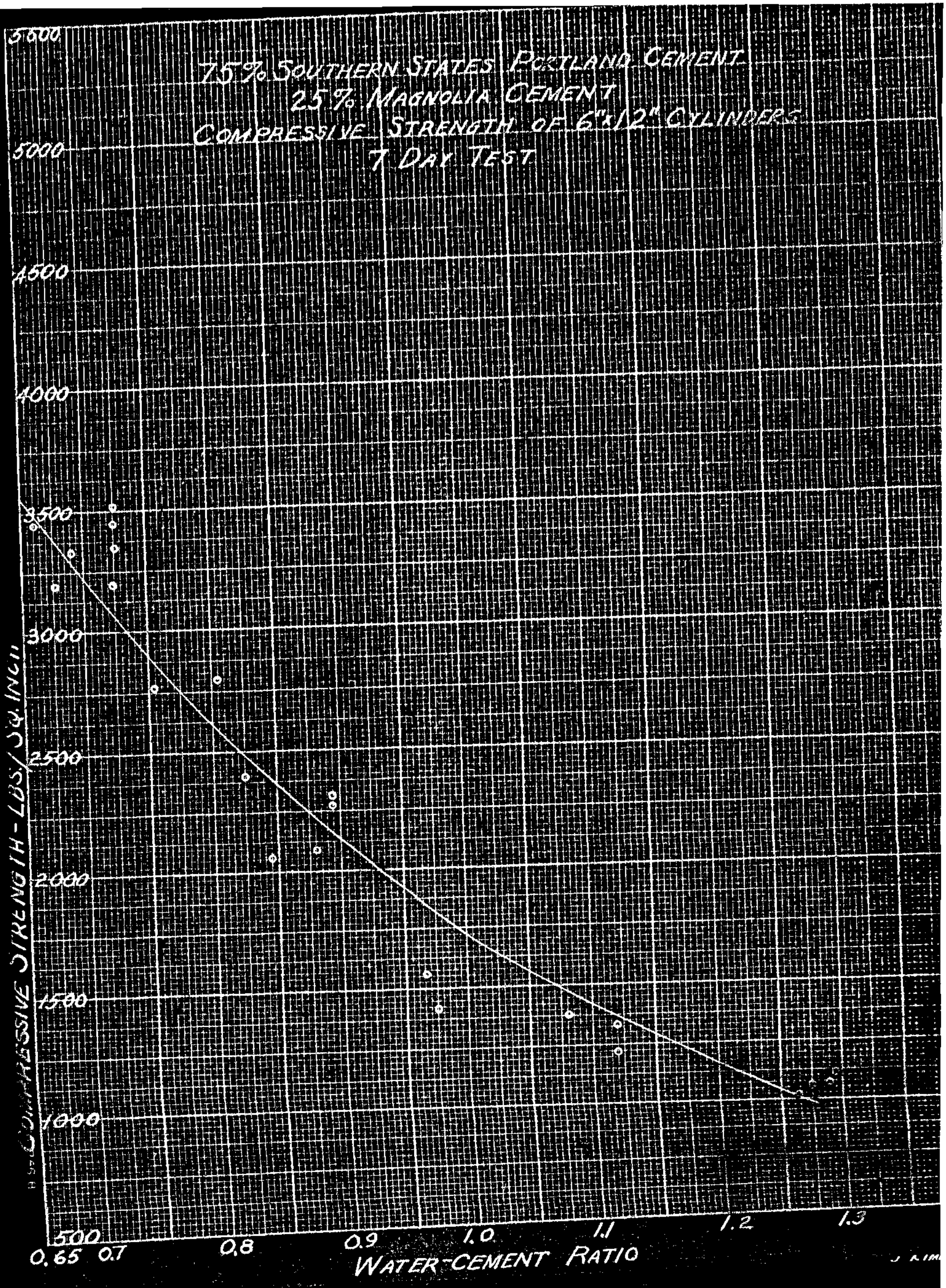
STRENGTH	W/C
1000 #/□"	1.271
1500	1.071
2000	0.929
2500	0.819
3000	0.728
3500	0.652
4000	0.586

4-23-39

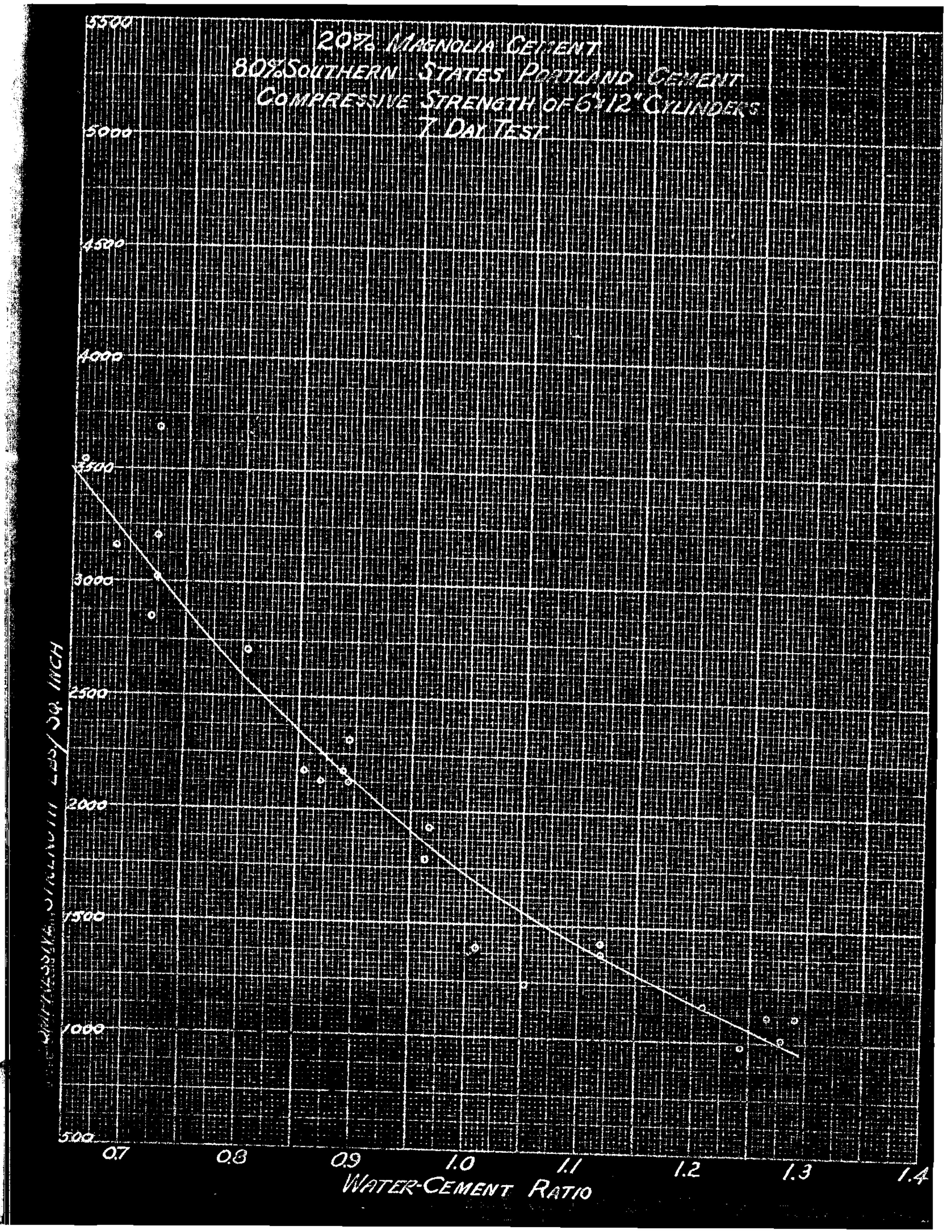
WATER-CEMENT RATIO


70% Southern States Portland Cement
30% Magnolia Cement
Compressive Strength of 6"x12" Cylinders
7 Day Test
Compressive Strength - Lbs./Sq. Inch
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
Water-Cement Ratio

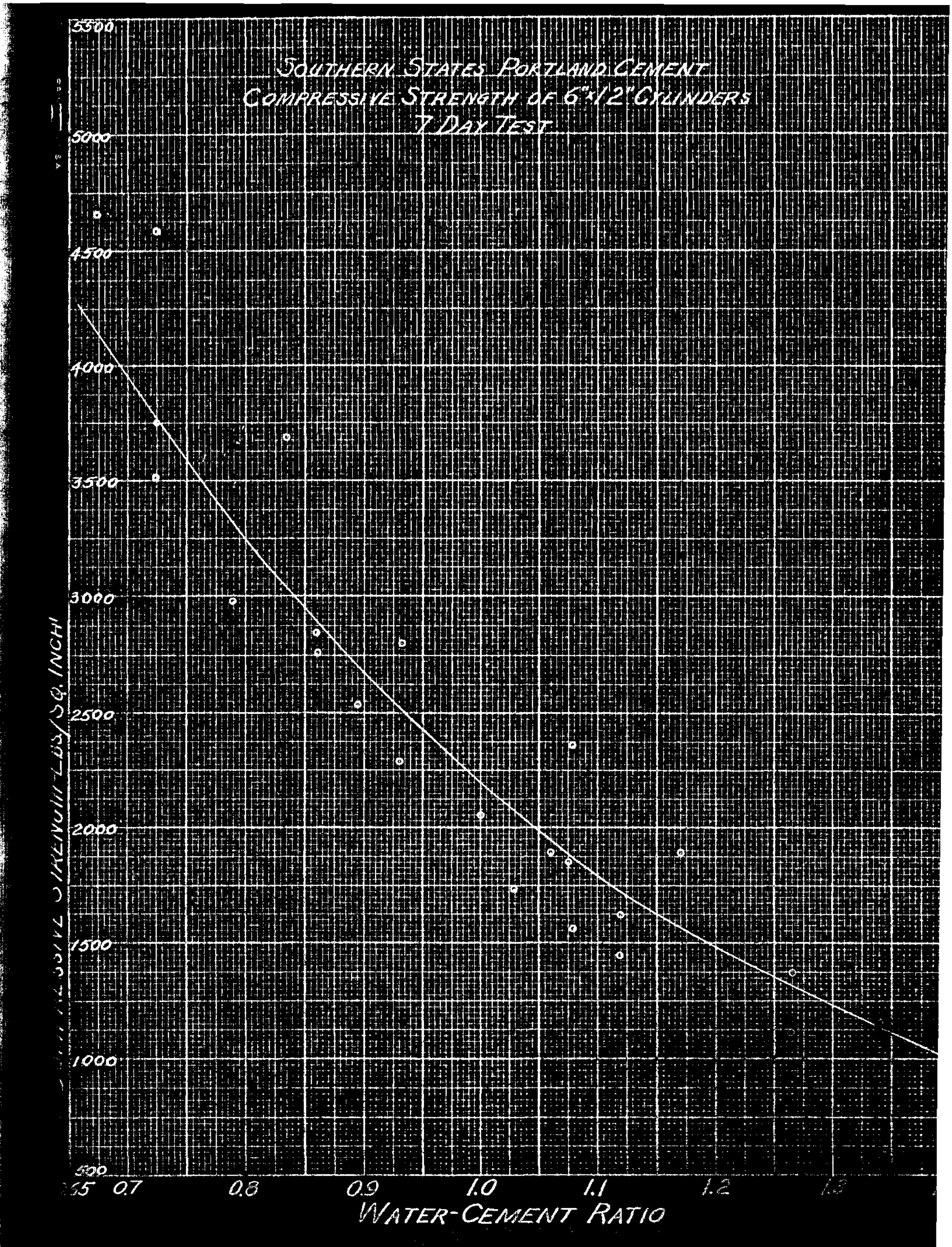

65% SOUTHERN STATES PORTLAND CEMENT
35% MAGNOLIA CEMENT
COMPRESSIVE STRENGTH OF 6"x12" CYLINDERS
7 DAY TEST
5500
5000
4500
4000
3500
3000
2500
2000
1500
500
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.44
WATER-CEMENT RATIO
J KIMMIER



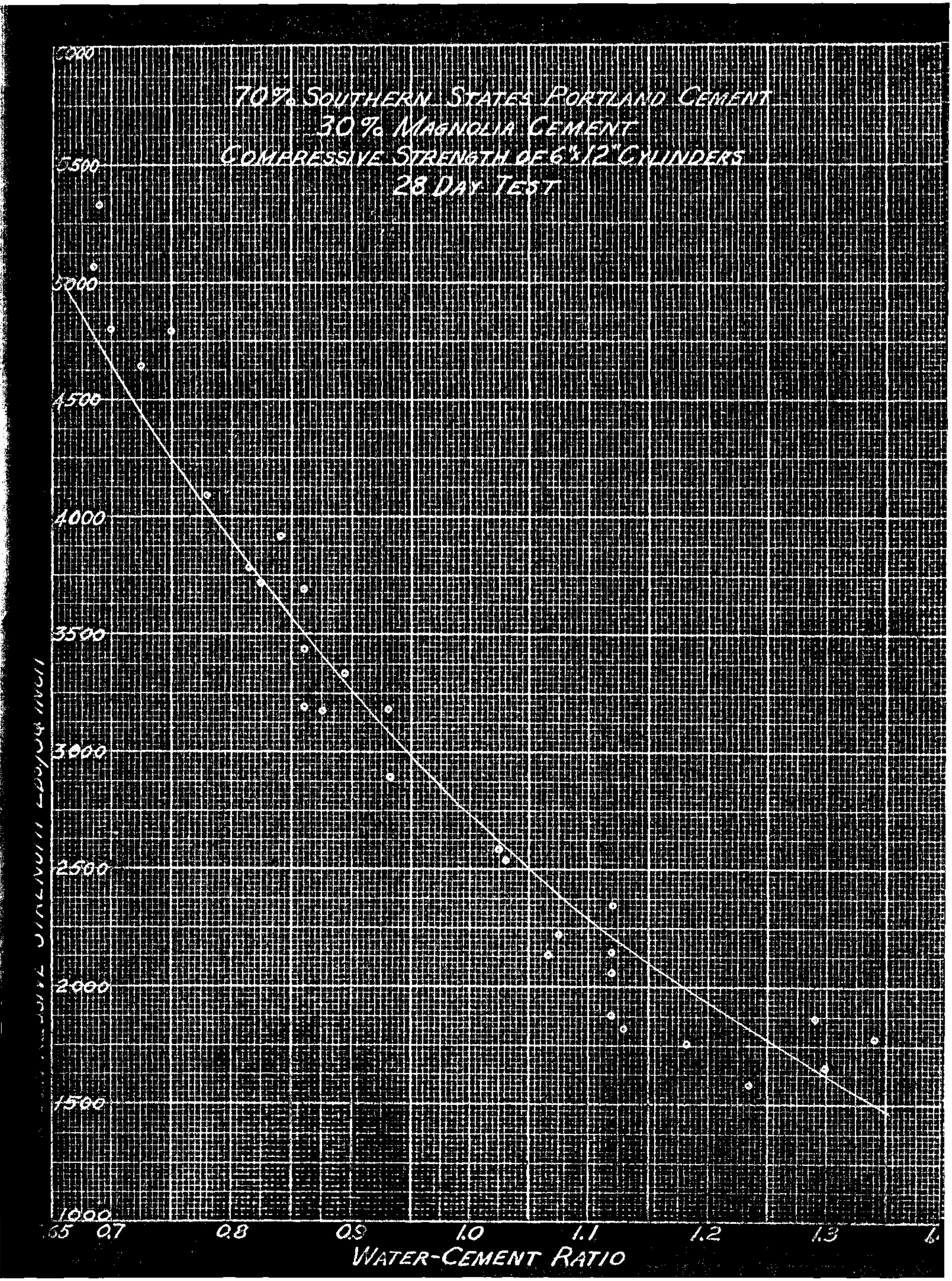
75% SOUTHERN STATES PORTLAND CEMENT
25% MAGNOLIA CEMENT
COMPRESSIVE STRENGTH OF 6"x12" CYLINDERS
7 DAY TEST
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
WATER-CEMENT RATIO
COMPRESSIVE STRENGTH - LBS./SQ. INCH

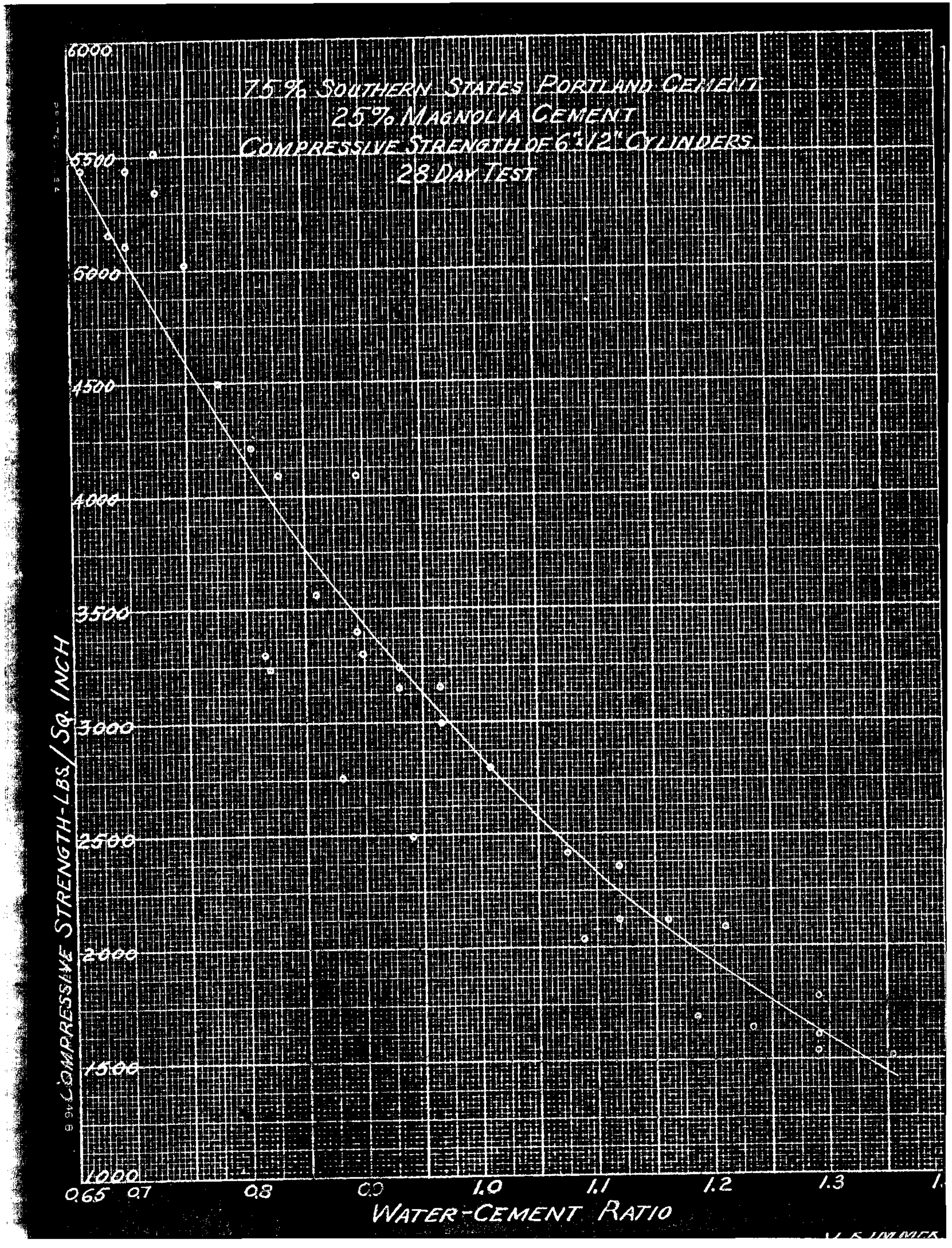


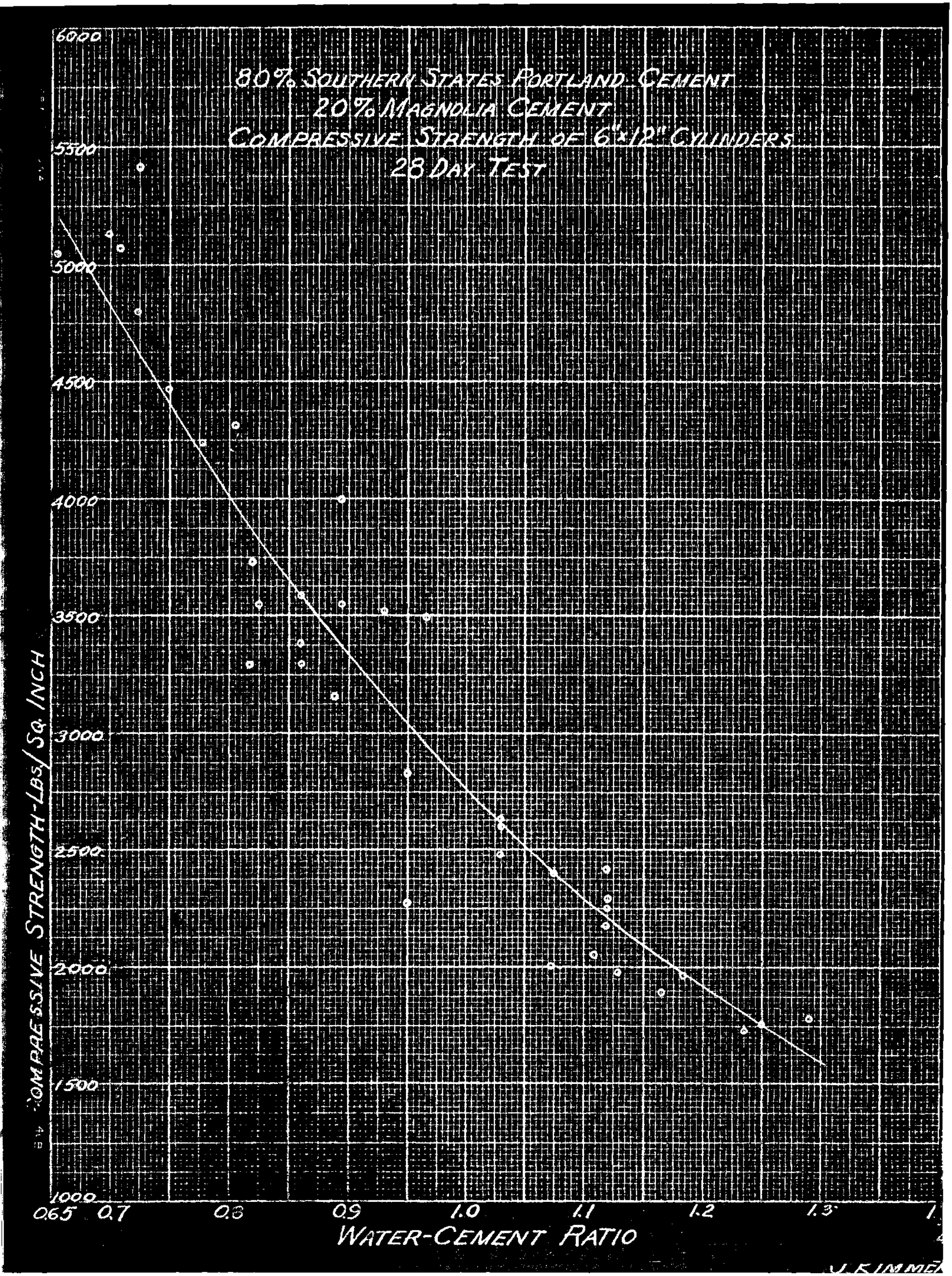
20% Magnolia Cement
80% Southern States Portland Cement
Compressive Strength of 6"x12" Cylinders
7 Day Test
Compressive Strength Lbs./Sq. Inch
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Water-Cement Ratio

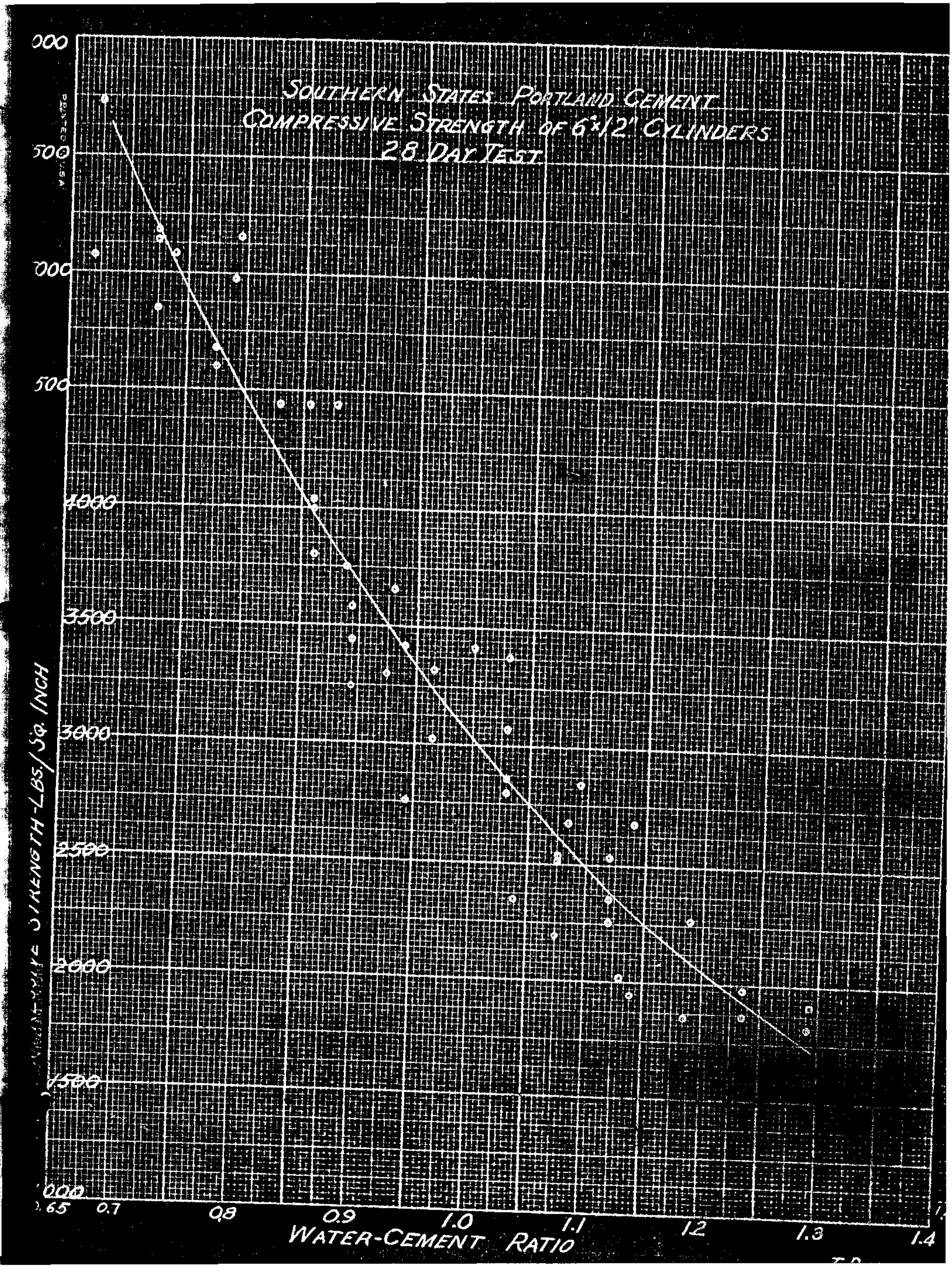


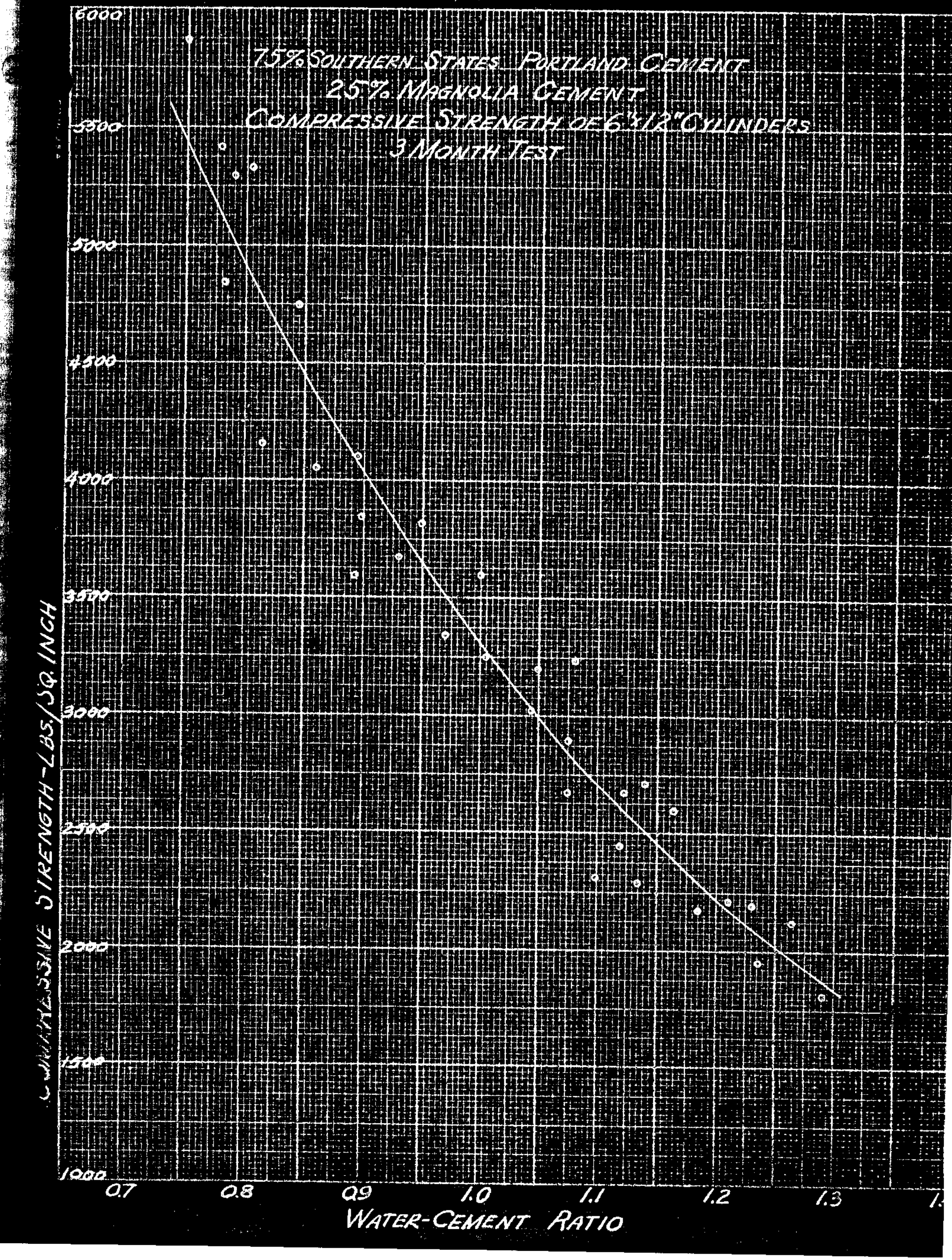
SOUTHERN STATES PORTLAND CEMENT
COMPRESSIVE STRENGTH OF 6"x12" CYLINDERS
7 DAY TEST
COMPRESSIVE STRENGTH LBS/SQ. INCH
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
WATER-CEMENT RATIO

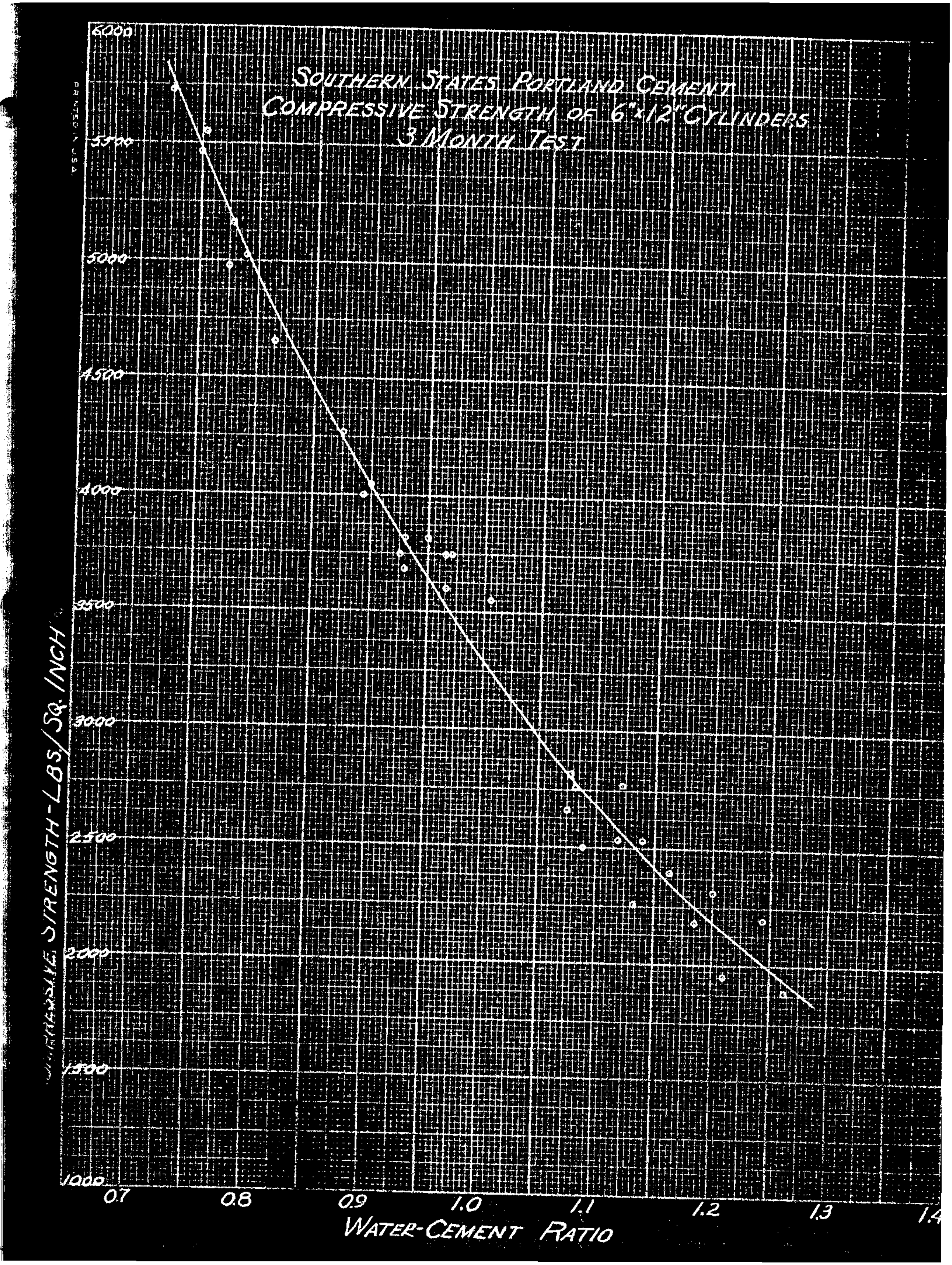

70% Southern States Portland Cement
30% Magnolia Cement
Compressive Strength of 6"x12" Cylinders
28 Day Test
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
Water-Cement Ratio


75% SOUTHERN STATES PORTLAND CEMENT
25% MAGNOLIA CEMENT
COMPRESSIVE STRENGTH OF 6"x12" CYLINDERS
28 DAY TEST
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
0.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
COMPRESSIVE STRENGTH-LBS./SQ. INCH
WATER-CEMENT RATIO

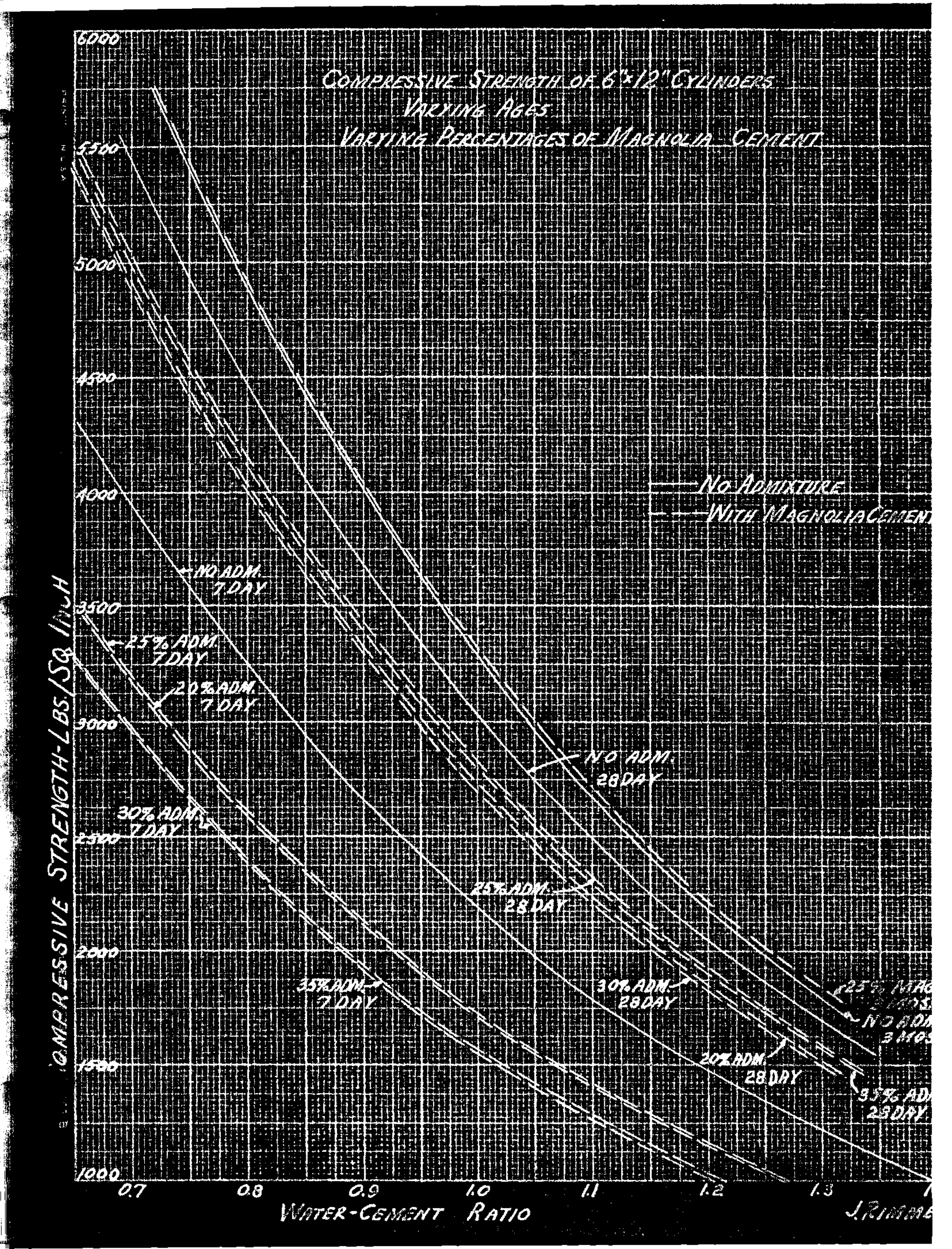

80% SOUTHERN STATES PORTLAND CEMENT
20% MAGNOLIA CEMENT
COMPRESSIVE STRENGTH OF 6"x12" CYLINDERS
28 DAY TEST
COMPRESSIVE STRENGTH-LBS/SQ. INCH
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
0.65
0.7
0.8
0.9
1.0
1.1
1.2
1.3
WATER-CEMENT RATIO

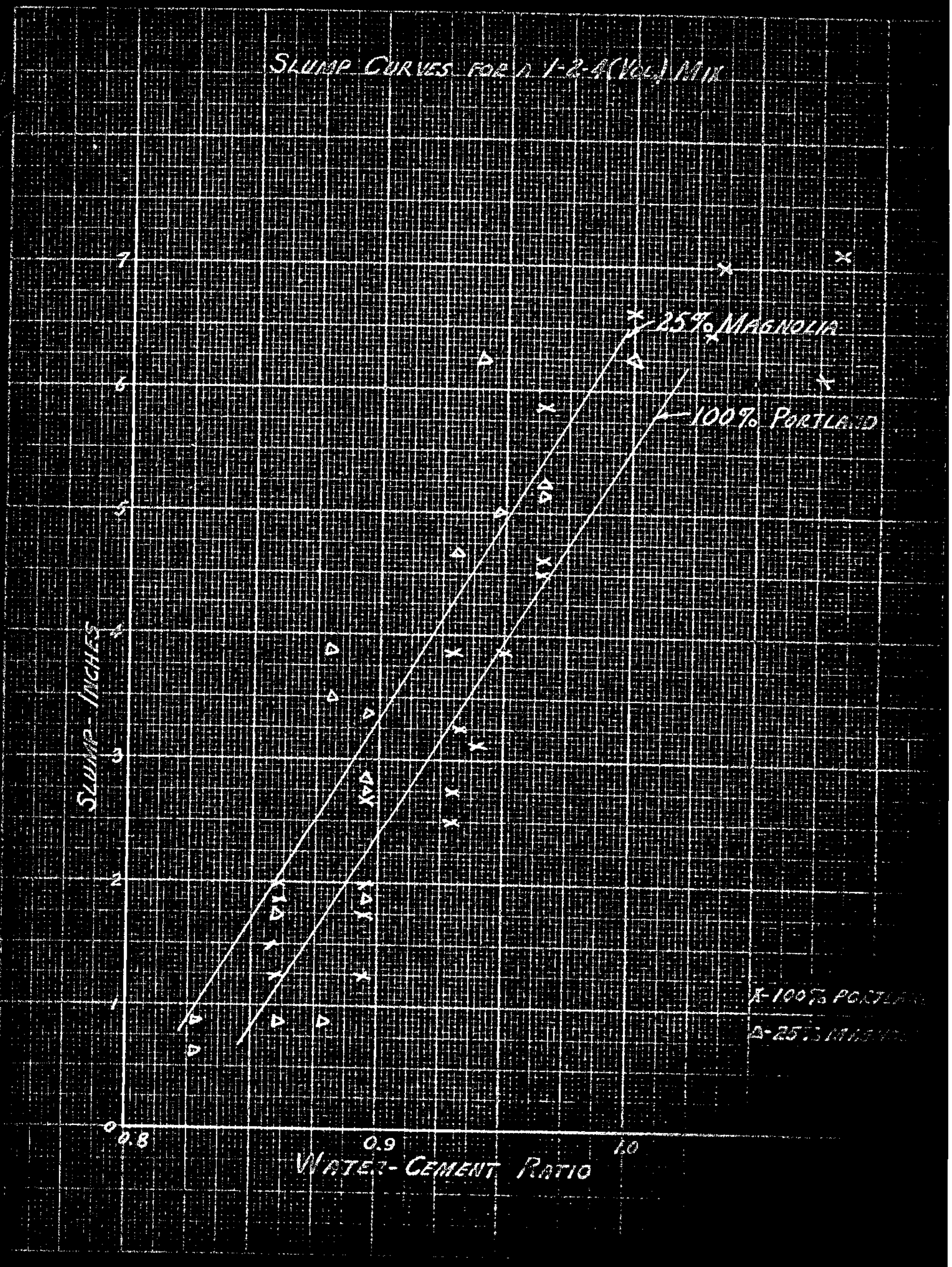

SOUTHERN STATES PORTLAND CEMENT
COMPRESSIVE STRENGTH OF 6"x12" CYLINDERS
28 DAY TEST
4000
3500
3000
2500
2000
1500
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
WATER-CEMENT RATIO
STRENGTH-LBS./SQ. INCH


75% SOUTHERN STATES PORTLAND CEMENT
25% MAGNOLIA CEMENT
COMPRESSIVE STRENGTH OF 6"×12" CYLINDERS
3 MONTH TEST
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
0.7
0.8
0.9
1.0
1.1
1.2
1.3
WATER-CEMENT RATIO
COMPRESSIVE STRENGTH-LBS./SQ. INCH



Southern States Portland Cement
Compressive Strength of 6"x12" Cylinders
3 Month Test
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
Compressive Strength - Lbs./Sq. Inch
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Water-Cement Ratio


COMPRESSIVE STRENGTH OF 6"×12" CYLINDERS
VARYING AGES
VARYING PERCENTAGES OF MAGNOLIA CEMENT
NO ADMIXTURE
WITH MAGNOLIA CEMENT
NO ADM. 7 DAY
25% ADM. 7 DAY
20% ADM. 7 DAY
30% ADM. 7 DAY
NO ADM. 28 DAY
25% ADM. 28 DAY
35% ADM. 7 DAY
30% ADM. 28 DAY
20% ADM 28 DAY
NO ADM 3 MOS
35% ADM 28 DAY
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
0.7
0.8
0.9
1.0
1.1
1.2
1.3
COMPRESSIVE STRENGTH-LBS./SQ. INCH
WATER-CEMENT RATIO
J. RIMME



SLUMP CURVES FOR A 1-2-4 (VOL.) MIX
25% MAGNOLIA
100% PORTLAND
SLUMP - INCHES
0
1
2
3
4
5
6
7
0.8
0.9
1.0
WATER - CEMENT RATIO
X - 100% PORTLAND
Δ - 25% MAGNOLIA

SOUTHERN CEMENT COMPANY

MANUFACTURERS OF

SLAG CEMENT

BIRMINGHAM, ALA. Oct. 31, 1938

Mr. J. S. Rimmer,
717 Techwood Drive,
Atlanta, Georgia.

Dear Mr. Rimmer:

The advantages to be gained by using a blend of MAGNOLIA SLAG CEMENT and Portland in concrete construction are as follows:

Greatly increased workability and plasticity
Decrease in water ratio
Less cracking on account of generating less Heat during hydrating period
Increased density of concrete, insuring a waterproof job if the concrete is placed with reasonable care
Increased strength on longer-time tests.

Concrete produced from Portland Cement is as a rule, harsh and lacks workability, the concrete requiring a great deal of rodding or spading in order to prevent honey-combing. Various means have been used in order to counteract this lack of workability, but in all instances some admixture has been used with varying success. These admixtures merely act as fillers and do not increase the volume of the concrete; consequently, are simply an added expense.

However, when using a blend of MAGNOLIA and Portland you are not putting the MAGNOLIA in as an admixture as you are actually replacing a portion of the Portland Cement with MAGNOLIA CEMENT.

The comparison of MAGNOLIA and Portland, from a chemical standpoint, shows about as follows:

	Lime (CaO)	Silica (SiO_2)
MAGNOLIA	49%	31.75
Portland Cement	64%	21.75%

You will note that MAGNOLIA is comparatively low in lime and high in silica, and when blending the two cements some of the active silica in MAGNOLIA evidently combines with the free lime in the Portland, forming mono-calcium silicates which have low early strengths but gain very rapidly as time progresses. This accounts for the excellent longer-time strengths on blended concrete as shown by accompanying tests.

Professor Duff A. Abrams is a recognized authority on cement and concrete mixtures - and we are very glad, indeed, to say that our finds, as supported by tests we are handing you are backed up by Professor Abrams in his Bulletin No. 8 entitled "EFFECTS OF HYDRATED LIME AND OTHER POWDERED ADMIXTURES IN CONCRETE". We enclose herewith extracts from Bulletin No. 8 which bear directly on mixing blast furnace slag with Portland Cement in concrete work.

We hand you herewith reports from the Pittsburgh Testing Laboratory, the Southern Testing Laboratories and our own Laboratory, showing the effect in the setting time of a blend of 50% Portland - 50% MAGNOLIA and 2/3 Portland - 1/3 MAGNOLIA. You will note that the setting time is not changed materially; however, cracking of concrete is eliminated almost entirely.

We are also handing you test on 6" cylinders, mixed 1-2-4, using 2/3 Portland - 1/3 MAGNOLIA -- time of test being 7 days, 28 days, 90 days and 6 months. You will notice in these tests a wonderful increase in strength as time progresses.

You will also find a 1 to 3 sand test with blue line print attached, showing 2" mortar cubes, using straight Portland Cement mortar, MAGNOLIA CEMENT mortar, and 50% Portland - 50% MAGNOLIA mortar.

While this test does not deal with concrete, it is very interesting, as it was upon the result of this test that we furnished our MAGNOLIA CEMENT in a blend with Portland - using a mix of 2/3 Portland - 1/3 MAGNOLIA to 50% Portland - 50% MAGNOLIA in the construction of MITCHELL DAM for the Alabama Power Company, which was the first job of any magnitude in which we had succeeded in selling a blend. This was a seven million dollar job and we are very glad to say that the actual work proved out most excellent in every way.

During the past twenty years our product has been used in a blend with Portland on some of the largest structures in the South -- and we list some of the outstanding jobs:

Mr. O. G. Thurlow, Chief Engineer
Alabama Power Company
Birmingham, Alabama,

has used MAGNOLIA in a blend with Portland in the following projects;

Mitchell Dam
Martin Dam
Upper Tallassee Dam
Lower Tallassee Dam
Lock No. 18 (Coosa River)
Furman Shoals Dam

- - - - - - - - - - - - - - - - -

Mr. C. T. Wanzer
Southern Power Company
Charlotte, N. C.,

has used MAGNOLIA in a blend with Portland in the following projects;

Hydro Project, Mt. Holly, N. C.
Cedar Creek Project, Nitrolee, S. C.
Fishing Creek Project, Wateree, S. C.

- - - - - - - - - - - - - - - - - -

Mr. W. E. Mitchell
Georgia Power Company
Atlanta, Georgia,

has used MAGNOLIA in a blend with Portland in the following projects;

Hydro Project, Tugalo, Georgia
Terrora Tunnels and Intake
Foundation, Terrora Power House
Yonah Project

- - - - - - - - - - - - - - - - - -

Mees & Mees, Consulting Engineers
(Mr. E. A. Mees is now Director of Water Research Division of the Natural Power Survey under the Federal Power Commission, Washington, D. C.)

Charlotte, N. C.,

have used MAGNOLIA in a blend with Portland in the following projects;

Multiple Arch Dam, Chimney Rock, N. C.
Turner Station Development, Tryon, N. C.
Hydro Project, Jackson's Bluff, Florida.

- - - - - - - - - - - - - - - - - - - -

We recently furnished MAGNOLIA CEMENT on ROCKY RIVER DAM at IVA, S. C. - Captain J. Roy Pennell of Pennell & Harley, Owners - Spartanburg, S. C.

The Tennessee Valley Authority used MAGNOLIA CEMENT in a section of NORRIS DAM in a blend of 25% MAGNOLIA - 75% low heat Portland Cement, and we are attaching a copy of their report and the two year test from the field mix.

We are enclosing list of other type of structures in which our product has been used in a blend with Portland.

Yours very truly,

SOUTHERN CEMENT COMPANY

Geo. D. Walter

General Manager.

GCW:MT

GE C. WALTER, VICE-PRES. & GEN. MGR. C. W. STREIT, JR., SECY. & SALES MANAGER W. J. CABANISS, ASST. SALES MANAGER

SOUTHERN CEMENT COMPANY

MANUFACTURERS OF

SLAG CEMENT

BIRMINGHAM, ALA. Oct. 31, 1938

Mr. J. S. Rimmer,
717 Techwood Drive,
Atlanta, Georgia.

Dear Mr. Rimmer:

Answering your letter of the 29th, we enclose herewith our regular blend letter which is sent out for advertising purposes, also Government tests and commercial laboratory tests.

We think this literature will give you all the information desired if you will study it carefully.

However, if there is any other data you want we will be very glad to be of any assistance that we can.

Yours very truly,

SOUTHERN CEMENT COMPANY
Geo C Walter
General Manager.

GCW:MT

Extracts from -

Bulletin No. 8
Structural Materials Research Laboratory
Lewis Institute
CHICAGO

EFFECT OF HYDRATED LIME AND OTHER
POWDERED ADMIXTURES
IN CONCRETE

By
DUFF A. ABRAMS - Professor in Charge of Laboratory

---

* * * * *
(Page No. 14)

Miscellaneous Powdered Admixtures in Concrete

**

In studying the effect of admixtures, curves were platted showing the relation between the strength of concrete and percentage of material added; see Fig. 1 to 5. In general these curves are essentially straight lines, consequently the slope represents the rate of change of strength with the percentages of admixtures. Most of these admixtures gave essentially the same results and showed the same effect as hydrated lime. Usual concrete mixtures were reduced in strength. The only exception to this statement is pulverized blast furnace slag. Gypsum gave a much greater reduction in strength than any of the other materials.

*****
(Page No. 16)
* *

SLAG. -- Granulated blast furnace slag ground in the laboratory to the fineness of Portland Cement. The results of tests with slag differed essentially from all other admixtures in that the strength of concrete was slightly increased for all quantities up to 50 per cent of the volume of the cement which was the highest value used. This statement applies to mixes from 1:9 to 1:4, for different consistencies and ages. The 1:3 mix showed a slight loss in strength with the addition of slag. For the conditions discussed for other admixtures the slag increased the strength 0.12 per cent for each 1 per cent added. A similar relation has been pointed out by other writers both in this country and Europe. This result has been explained as due to chemical reactions between the slag and certain compounds in the cement. The principal constituents of this slag were: SiO_2, 34.8 per cent; CaO, 42.6 per cent; Al_2O_3, 15.0 per cent; Fe_2O_3, 3.7 per cent.

*****
(Page No. 17)
* *

Effect of Admixtures on the Wear of Concrete

Three different groups of wear tests were carried out; see Tables 11, 20 and 21. All wear tests were made in the Talbot-Jones rattler, using 8x8 by 5-in. concrete blocks. The wear blocks were tested at 3 months after 14 days in damp sand, followed by air storage. Wear tests were made with admixtures of hydrated lime, kieselguhr, Powdered Limestone, slag, sand, and natural cement. This test was of such severity as to produce a wear of 0.4 to 0.5 in.

Slag showed the best results since the wear was no greater with 33 per cent slag than with straight cement; sand gave nearly as good results as slag; the other admixtures may be placed in the following order of merit; hydrated lime, natural cement, limestone and kieselguhr. There seems to be little reason for using these materials in concrete roads and other concrete subjected to wear; it is of interest to know that some of them do little or no harm. The principal danger from the use of admixtures in road concrete is that any excess of mixing water will cause the fine material to be floated to the surface and thus give concrete of inferior wearing resistance. The same statement applies to silt in sands and to crusher dust. Silt may contain organic impurities which materially reduce the strength of concrete.

*****
(Page No. 19)

Conclusions

(5). Pulverized Slag up to 50 per cent of volume of cement gave a slight increase in strength of concrete (about 0.12 on the basis used above).

*****

(9). Sand and slag cements gave results comparable to those from powdered materials simply mixed in the concrete.

* * * * *

(C O P Y)